Simulation of granular shear flow

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粉体をガス状に分散させた系にせん断をかけた際の応答を数値的に調べた。粒子間散逸によって密度相分離が生じるが、その相分離の性質は粒子間接触力の接線成分の存在に大きく依存することが分かった

Flow of Granular materials behaves as an unusal fluid, and its rheology has not been well understood. In this poster, we focus on Couette flow of granular gases which may be one of simplest flows in the usual situation. As is well known, the conventional Couette flow is characterized by the linear velocity profile as a function of position. This linear profile can be reproduced from the molecular dynamic simulation without dissipation between particles. However, the velocity profile of granular Couette flow dose not obey a linear function.

Here, we adopt the two-dimensional discrete-element method(DEM) to simulate dynamical behaviors of granular particles. The system is in a rectangular box with the linear dimension of x and y directions are respectively given by L and H. We apply the shear force in x direction with the shear speed $\pm 4.0\sqrt{gd}$ with the gravitational accerelation g and the diameter of particles d. We adopt a bumpy boundary condition on the sheared wall at $y = \pm H/2$ and adopt the periodic boundary condition at $x = \pm L/2$. Here we place a random set of fixed hemi-circular particles on the sheared wall to produce the bumpy boundary condition. DEM contains the contact repulsive force which has both the normal component and the tangential component.

At first we have confirmed that our DEM without dissipation and the tangential contact force reproduces a linear velocity profile. Second, we introduce dissipations in the contact force. Through our simulation we adopt the normal restitution coefficient $e = 0.79$ and the area fraction $\phi = 0.10, 0.39, 0.52$ and the number of particles is 3000.

We should note that similar Couette flow has been discussed by Tan and Goldhirsh[1], but their model dose not contain any tangential contact force. In this poster, we stress the role of tangential contact force in Couette flow. In both cases with the tangential force and without the tangential force, the velocity profile becomes nonlinear, the granular temperature becomes small and the density becomes large in the center region of steady Couette flow.

The transient dynamics to reach a steady state strongly depends on whether the tangential contact force exists. When the tangential force is included, the system is in a long lived

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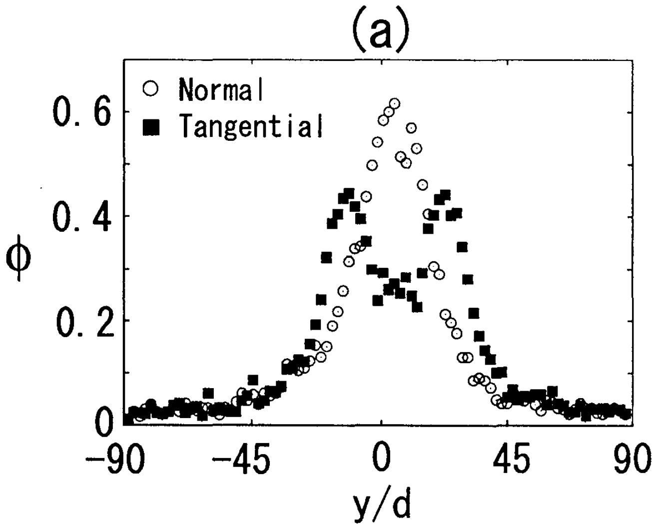
metastable state in which the velocity and the granular temperature in the center region become almost zero. We also find an interesting transient dynamics of the density field where two dense clusters appears and merge to a dense cluster in the center region. This behavior has only been observed in the case of DEM with the tangential contact force.

In this poster we will present our current results we have obtained. We also discuss the possibility of the theoretical analysis based on granular hydrodynamics[2] and the effect of particles' rotation in granular hydrodynammics.[3]



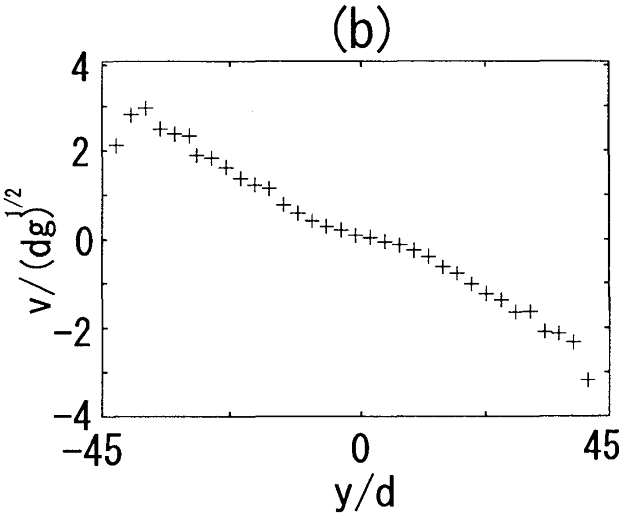


Figure 1: (a) The transient area fraction ϕ as a function of y at $t = 150\sqrt{g/d}$. The solid squares (Tangential) and the oepn circles (Normal) are the data with the tangential force and without the tangential force. We use that the average area fraction is 0.52, and $H = 180d$. (b) The steady velocity profile with ϕ =0.39 and $H = 90d$. The other parameters are the same as those in (a).

References

[1] M.-L. Tan, and I. Goldhirsch, Phys.Fluids **9** (1997), 856.

[2] P. R. Nott and M. Alam et al, J.Fluid Mech. **397** (1999), 203.

[3] I. Goldhirsch, S. H. Noskowicz, and O. Bar-Lev, to be published in Phys. Rev. Lett.